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(54) Complex magnesium alloy member and method for producing same

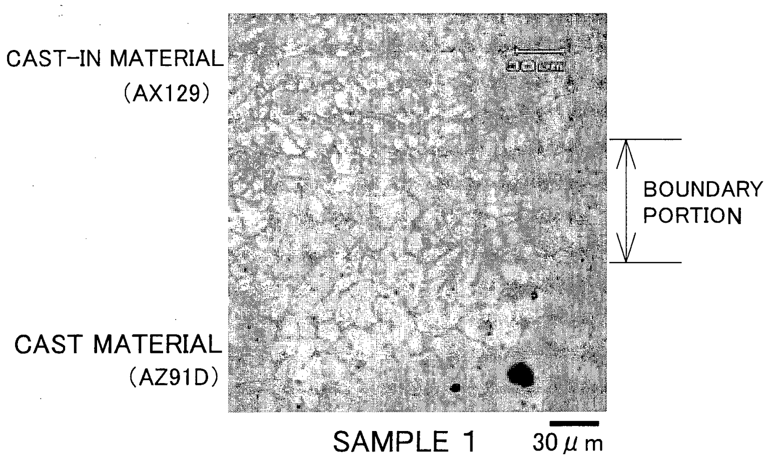
(57) [Problem]

An object is to provide a complex magnesium alloy member in which magnesium alloys having different alloy compositions are merged into each other.

[Solving means]

The complex magnesium alloy member according to the present invention comprises: a first portion comprising a first magnesium alloy having a first alloy composition; a second portion comprising a second magnesium alloy having a second alloy composition different from the first alloy composition; and a boundary portion comprising an intermediate magnesium alloy having an intermediate alloy composition between the first alloy composition and the second alloy composition, the boundary portion merging into and abutting the first portion and the second portion to form a boundary between the first portion and the second portion. Such a complex magnesium alloy member can be obtained such as by casting a cast material that has a high liquidus temperature with a magnesium alloy cast-in material that has a low liquidus temperature. According to the complex magnesium alloy member of the present invention, a magnesium alloy product can be obtained at low cost, which has different characteristics depending on the sites thereof.

FIG.1A



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Description

[Technical Field]

[0001] The present invention relates to a complex magnesium alloy member configured such that magnesium alloys having different alloy compositions are merged into one another, and a method for producing the same.

[Background Art]

[0002] Magnesium (Mg) is the most lightweight metal among practical metals and has a high specific strength, and resources of magnesium are rich. In recent years where weight saving and reduction of environmental burdens etc. are strongly needed, magnesium is a promising metal material, and magnesium alloys have been being used for various products.

[0003] Magnesium alloys have different characteristics depending on their alloy compositions, so that an appropriate alloy composition for each product has been selected. Indeed, the conventional magnesium alloy product may have been such that the whole is formed of the same alloy composition, or may have been a cast member (complex member) in which the magnesium alloy is cast with a heterogeneous member (cast-in material) such as formed of steel material to a site where a certain strength and/or stiffness are required. As for the latter cast member, relevant descriptions are disclosed in Patent Literature below, for example.

[Citation List]

[Patent Literature]

[PTL 1]

[0004] Japanese Unexamined Patent Application Publication No. 9-183379

[Summary of Invention]

[Technical Problem]

[0005] The conventional cast member as disclosed in Patent Literature 1, however, may readily cause delamination or other troubles at the bonded interface between the cast-in material (steel material) and the cast material (magnesium alloy), and cannot be used for a product that requires hermetic properties, such as liquid-tightness and gas-tightness. In addition, production cost of the cast member becomes high because the cast-in material may have to be preliminarily formed thereon with retaining grooves or other appropriate means by machining process.

[0006] The present invention has been created in view of such circumstances, and objects of the present invention include providing a complex magnesium alloy member in which, different from the conventional cast member and other members, magnesium alloys having different alloy compositions are integrated with one another, and also providing a method for producing the same.

[Solution to Problem]

[0007] As a result of intensive studies to solve such problems and repeating trial and error, the present inventors have successfully obtained a complex magnesium alloy cast having heat resistance property and casting ability by casting a molten magnesium alloy of high casting ability with a magnesium alloy member (cast-in material) of high heat resistance property. It has been found that this complex magnesium alloy cast does not have any sharply-defined bonded interface between the cast-in material and the cast material so that a state is obtained where both materials are continuously merged into each other. Developing this achievement, the present invention has been accomplished as will be described hereinafter.

«Complex magnesium alloy member»

[0008]

(1) The complex magnesium alloy member according to the present invention is characterized by comprising: a first portion comprising a first magnesium alloy having a first alloy composition; a second portion comprising a second

magnesium alloy having a second alloy composition different from the first alloy composition; and a boundary portion comprising an intermediate magnesium alloy having an intermediate alloy composition between the first alloy composition and the second alloy composition, the boundary portion merging into and abutting the first portion and the second portion to form a boundary between the first portion and the second portion.

(2) The complex magnesium alloy member (referred also to as "complex member") according to the present invention is configured such that magnesium alloys having different alloy compositions are integrated via the boundary portion. Unlike the conventional magnesium alloy member formed of single alloy composition, this complex magnesium alloy member according the present invention can develop different characteristics depending on sites thereof. For example, the large part may be configured of a magnesium alloy having excellent casting ability to ensure the productivity while a site requiring high-temperature strength or other properties may be configured of a magnesium alloy having excellent heat resistant property.

[0009] Thus, according to the present invention, a complex member can be obtained in which an appropriate magnesium alloy can be located at an appropriate location and which can enhance the mechanical characteristics and other properties as well as reduce the raw material cost, and further improve the productivity, such as casting ability. Of course, the complex member according to the present invention may be such that the whole is formed of magnesium alloys, thereby not impairing the lightweight property, and necessary treatment such as heat treatment and machining process can be conducted like in the prior art, and recyclability etc. may be sufficient when discarded.

[0010] Meanwhile, the boundary portion according to the present invention between the abutting first portion and second portion is a portion in which the first magnesium alloy that constitutes the first portion and the second magnesium alloy that constitutes the second portion are merged into each other, and thus different from a bonded portion such as caused by pressure bonding and adhesion. More specifically, the boundary portion comprises the intermediate magnesium alloy having the intermediate alloy composition between the first magnesium alloy (first alloy composition) and the second magnesium alloy (second alloy composition). This intermediate magnesium alloy is in general such that the alloy composition varies continuously or gradually along from the first magnesium alloy to the second magnesium alloy. In other words, the boundary portion according to the present invention does not comprise a sharply-defined interface at which the alloy composition and the structure etc. rapidly vary. Thus, the boundary portion according to the present invention is configured of a boundary region (the width may be about several to several tens micro meters) in which the alloy composition varies relatively gently between the abutting magnesium alloys. Such a state where the first portion and the second portion are integrated via the boundary portion is referred herein to as "merging" or "being merged".

[0011] In any event, the complex member according to the present invention is configured such that magnesium alloys having different alloy compositions are continuously integrated as if they act as one magnesium alloy bulk. Therefore, unlike in the conventional cast member, troubles such as delamination and liquid-leakage may not occur at the boundary portion. Moreover, both sides of the boundary portion are provided with the same kind of metal (magnesium alloys), so that any intermetallic compound or the like (crystallized substance or precipitated substance), which is likely to be formed between dissimilar metals in general, may not be formed in the boundary portion, and the boundary portion can thus be prevented from being fracture origin. Furthermore, the first portion and the second portion according to the present invention merge into each other in the boundary portion thereby to enhance the heat conductivity and the electrical conductivity etc. between the first portion and the second portion.

«Method for producing complex magnesium alloy member»

[0012]

(1) The above complex magnesium alloy member can easily be obtained, such as, but not limited to, by the production method as below. That is, the method for producing a complex magnesium alloy member according to the present invention is characterized by comprising: a locating step that locates a cast-in material in a cavity of a mold, the cast-in material comprising a first magnesium alloy having a first alloy composition; a pouring step that pours a molten alloy into the cavity, the molten alloy comprising a second magnesium alloy having a second alloy composition, the second magnesium alloy having a liquidus temperature higher than that of the first magnesium alloy; and a solidification step that cools and solidifies the molten alloy to obtain a complex magnesium alloy member in which a cast material comprising the second magnesium alloy is cast with the cast-in material.

(2) According to the production method of the present invention, the liquidus temperature of the first magnesium alloy that constitutes the cast-in material is lower than the liquidus temperature of the second magnesium alloy that constitutes the molten alloy, so that the first magnesium alloy molten in the vicinity of the surface of the cast-in material and the molten alloy of the second magnesium alloy are present in a mixture state during from the pouring

step to the solidification step. This portion is solidified to remain in that state thereby to result in a state where the cast-in material and the cast material are merged into and bonded to each other, and the above complex magnesium alloy member of the present invention can thus be obtained.

[0013] Note that the form of the cast-in material, the shape of the cavity, the casting conditions and other factors in the production method of the present invention may not be limited. Note also that at least a part of the cast-in material may be heated before the pouring step thereby to adjust the form of the bonded portion (boundary portion) formed between the cast-in material and the cast material. Note further that the complex magnesium alloy member obtained after the solidification step may additionally be subjected to at least one subsequent step, such as heat treatment or plastic working.

«Others »

[0014]

(1) Examples of the "magnesium alloy member" as referred to herein include cast products (which may be obtained merely by casting or obtained by casting and additional processes such as heat treatment and working) as well as materials such as ingot, bulk material, rod-like material, tubular material and plate-like material etc. The "cast" may be obtained, such as, but not limited to, by gravity casting or pressure casting (such as die-casting), and any mold may be used, such as metal mold and sand mold.

(2) The terms "first" and "second" as used herein are merely for descriptive purposes to explain the present invention, and the magnesium alloys abutting via the boundary portion are not limited to two types, but may be three or more types. For example, a first magnesium alloy and a second magnesium alloy that have different alloy compositions may be merged into each other via a first boundary portion, while the second magnesium alloy and a third magnesium alloy that have different alloy compositions may be merged into each other via a second boundary portion.

(3) The "modifying elements" as referred to herein are elements, such as Al, Ca and other appropriate elements as well as Zn, Mn, R. E. (rare-earth elements), Be, Sn, Si, Sr, Bi, Zr and other appropriate elements, which may be effective to enhance the characteristics of the magnesium alloy. The types of the characteristics to be enhanced may be, such as, but not limited to, strength, toughness, ductility, heat resistance, and/or casting ability. Any combination of these elements may be possible, and the content thereof is extremely small in general. The "inevitable impurities" are impurities such as contained originally in the raw material and/or mixed during the production steps, such as Cu, Ni and Fe, which may be elements that are difficult to be removed for the cost or technical reason or other reasons.

(4) Unless otherwise stated, a numerical range "x to y" as used herein includes the lower limit value x and the upper limit value y. Various numerical values or any numerical value included in various numerical ranges described herein may be used as a new lower limit value or upper limit value, and any numerical range such as "a to b" may thereby be newly provided.

[Brief Description of Drawings]

[0015]

[Fig. 1A]
Fig. 1A is a photograph that shows the metallographic structure of and in the vicinity of the bonded portion (boundary portion) of a complex member according to Sample 1.
[Fig. 1B]
Fig. 1B is a photograph that shows the metallographic structure of and in the vicinity of the bonded portion (interface) of a complex member according to Sample C1.
[Fig. 1C]
Fig. 1C is a photograph that shows the metallographic structure of and in the vicinity of the bonded portion (boundary layer) of a complex member according to Sample C2.

[Description of Embodiments]

[0016] The present invention will be described in more detail with reference to embodiments of the present invention.

The contents described herein may be applied not only to the complex magnesium alloy member but also appropriately to a method for producing the same. Features regarding the production method, when understood as a product-by-process claim, may also be features regarding a product. One or more features freely selected from the description herein may be added to the above-described features of the present invention. Which embodiment is the best or not is different in accordance with objectives, required properties and other factors.

«Alloy composition»

[0017]

(1) So long as the boundary portion according to the present invention is formed, the alloy compositions of the abutting magnesium alloys are not limited. From the research by the present inventors, however, it has been found that an appropriate boundary portion is formed if the difference between the liquidus temperatures of the abutting magnesium alloys is a certain value or more. For example, the abutting magnesium alloys may preferably have alloy compositions (the first alloy composition and the second alloy composition) such that the temperature difference (|TL1-TL2|) between the liquidus temperature (TL1) of the first magnesium alloy and the liquidus temperature (TL2) of the second magnesium alloy is 10 degrees C or more, 15 degrees C or more, 30 degrees C or more, or further 40 degrees C or more. As will be appreciated by one of ordinary skill in the art, the liquidus temperature as referred to herein is a temperature determined from the phase diagram depending on the alloy composition, which is the minimum temperature at which the alloy completely melts.

[0018] So long as such a liquidus temperature difference is caused, the first alloy composition is not limited, but may preferably comprise, when the whole thereof is assumed to be 100 mass% (referred simply to as "%"), Al: 5-18%, Ca: 1-12%, and the balance: Mg and modifying elements or inevitable impurities, for example. The magnesium alloy having this alloy composition may develop excellent heat resistance due to Ca even without using expensive rare elements and cause the liquidus temperature (TL1) to be relatively low. The liquidus temperature may be 530 to 600 degrees C depending on the alloy composition.

[0019] On the other hand, the second alloy composition may preferably comprise, when the whole thereof is assumed to be 100%, Al: 2.5-15% and the balance: Mg and modifying elements or inevitable impurities. The magnesium alloy having this alloy composition may have versatility and excellent casting ability and allow magnesium alloy products to be produced efficiently at low cost by die-casting etc. The liquidus temperature (TL2) is relatively high, and may be 580 to 640 degrees C depending on the alloy composition.

(2) Specific alloy composition of the intermediate magnesium alloy that constitutes the boundary portion is not limited if the intermediate magnesium alloy has the above intermediate alloy composition between the first alloy composition and the second alloy composition. The intermediate alloy composition is not fixed in general, and may vary within a range having the upper and lower limits based on the first alloy composition and the second alloy composition. Note that the alloy composition as referred to herein is an alloy composition of a macro region that has a certain degree of expansion rather than being an alloy composition of a micro (local) region that constitutes the metallographic structure. Note also that the alloy composition and the width of the boundary portion can be adjusted by the liquidus temperatures (TL1 and TL2) and/or production conditions for the complex member (such as the molten alloy temperature, the molten alloy holding time, and the solidification rate).

«Use application»

[0020] The use application of the complex member according to the present invention is not limited. However, the complex member according to the present invention may be suitable as a member in which various sites require different characteristics. Examples of such a member include various cases and containers in which only the site to be connected with another member requires heat resistance and/or strength.

[Examples]

«Preparation of samples»

[0021] As shown in Table 1, samples were prepared as a plurality of complex members each produced by casting, with a cast-in material comprising its respective alloy composition (first alloy composition), a cast material comprising an alloy composition (second alloy composition) different from the first alloy composition.

[0022] The cast-in material is a cylindrical solid piece (diameter: 20 mm, height: 10 mm) cut out from an ingot obtained by gravity casting using a boat-shaped steel mold. For preparation of the molten alloy during the casting, commercially available alloy or pure metal was used as a raw material. The same applies to the cast material that will be described later. Symbols shown in columns of alloy compositions in Table 1 comply with ASTM standard or JIS which represents each alloy composition.

[0023] The above cylindrical solid piece was set at the center area of a die-casting mold having a cavity with cylindrical shape (diameter: 50 mm, height: 30 mm) (locating step). Each molten alloy for the cast material as shown in Table 1 was poured into the cavity at the molten alloy temperature shown in the table (pouring step). Thereafter, the mold was cooled to solidify the cast material, and a complex member was obtained to be cast therein with the cylindrical solid piece (solidification step).

[0024] This operation was conducted under die-casting conditions of the injection speed: 0.4 m/s and the injection pressure: 64 MPa.

«Observation»

[0025] The midsection of each obtained complex member was cut, and the cross-section was subjected to observation of the structure using an optical microscope. Fig. 1A to Fig. 1C are photographs each showing the metallographic structure of the bonded portion between the cast-in material and the cast material obtained in such a manner. Note that the metallographic structure of Sample 2 was substantially the same form as that of Sample 1 (Fig. 1A).

«Evaluation»

[0026] As seen from Fig. 1A (Sample 1), it has been confirmed that the cast material (second magnesium alloy /second portion) having a relatively high liquidus temperature is cast with the cast-in material (first magnesium alloy /first portion) having a relatively low liquidus temperature thereby causing both magnesium alloys to merge into each other within a region of a certain width, and a bonded portion by melting (boundary portion) is formed in which the alloy composition continuously varies.

[0027] In contrast, as seen from Fig. 1B (Sample C1), it has been found that, even in the case where both the cast-in material and the cast material are magnesium alloys, if the liquidus temperature of the cast-in material is higher than that of the cast material, then a bonded portion by non-melting (interface) is formed at which the magnesium alloys do not merge into each other. In addition, as apparent from Table 1, it has also been found that, even if the molten alloy temperature during the casting of the cast material is higher than the liquidus temperature of the cast-in material, the metallographic structure as shown in Fig. 1B is obtained. This appears to mean that a similar metallographic structure of the bonded portion will of course be obtained like in Fig. 1B if the molten alloy temperature is lower than the liquidus temperature of the cast-in material.

[0028] As apparent from Fig. 1C (Sample C2), it has also been found that, even in the case where the liquidus temperature of the cast-in material is lower than that of the cast material, if they have different main components (types of basis), then any bonded portion (boundary portion) as shown in Fig. 1A cannot be obtained. It has further been found that a boundary layer comprising an intermetallic compound (Al-Mg compound) based on those main components appears in the bonded portion between the cast-in material and the cast material. Such a boundary layer may cause deterioration in strength of the complex member.

[0029] As described above, it has been confirmed that a limited condition allows the boundary portion to be formed between the cast-in material and the cast material merging into each other. That is, it has been found that an appropriate boundary portion as referred to in the present invention can be formed if both the cast-in material and the cast material comprise magnesium alloys and the liquidus temperature of the cast material is higher than that of the cast-in material.

[Table 1]

Sample No.	Complex member					Liquidus temperature difference |TL1- TL2| (°C)	Evaluation
	Cast-in material		Cast material				
	Alloy composition (mass%)	Liquidus temperature TL1 (°C)	Alloy composition (mass%)	Molten alloy temperature (°C)	Liquidus temperature TL2 (°C)		
1	Mg-12%Al-9%Ca-0.3%Mn (AX129)	541	Mg-9%Al-0.7%Zn-0.3%Mn (AZ91D)	640	595	54	Bonded portion by melting was formed with the structure continuously varying
2	Mg-7%Al-5%Ca-0.3%Mn (AX75)	593	Mg-696Al-0.39%Mn (AM60B)	655	610	17	Bonded portion by melting was formed with the structure continuously varying
C1	Mg-4%Al-4%R.E.-0.2%Mn (AE44)	622	Mg-9%Al-0.7%Zn-0.3%Mn (AZ91D)	670	595	-27	Bonded portion by non-melting was formed
C2	Al-11%Si-2.5%Cu (ADC12)	580	Mg-9%Al-0.7%Zn-0.3%Mn (AZ91D)	655	595	15	Boundary layer was formed with crystallized intermetallic compound

Claims

1. A complex magnesium alloy member comprising:

a first portion comprising a first magnesium alloy having a first alloy composition;
a second portion comprising a second magnesium alloy having a second alloy composition different from the first alloy composition; and
a boundary portion comprising an intermediate magnesium alloy having an intermediate alloy composition between the first alloy composition and the second alloy composition,
the boundary portion merging into and abutting the first portion and the second portion to form a boundary between the first portion and the second portion.

2. The complex magnesium alloy member as recited in claim 1, wherein the first alloy composition and the second alloy composition are compositions such that a temperature difference (|TL1-TL2|) between a liquidus temperature (TL1) of the first magnesium alloy and a liquidus temperature (TL2) of the second magnesium alloy is 10 degrees C or more.

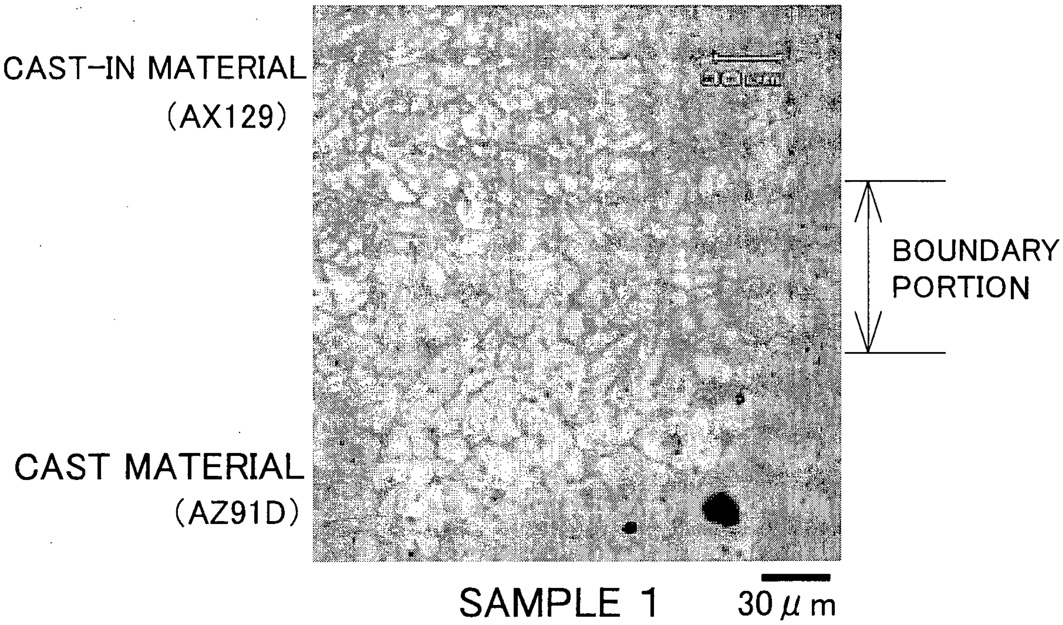
3. The complex magnesium alloy member as recited in claim 1 or 2, wherein
the first alloy composition comprises, when whole thereof is assumed to be 100 mass% (referred simply to as "%"), Al: 5-18%, Ca: 1-12%, and the balance: Mg and modifying elements or inevitable impurities, and
the second alloy composition comprises, when whole thereof is assumed to be 100%, Al: 2.5-15% and the balance: Mg and modifying elements or inevitable impurities.

4. A method for producing a complex magnesium alloy member, the method comprising:
a locating step that locates a cast-in material in a cavity of a mold, the cast-in material comprising a first magnesium alloy having a first alloy composition;
a pouring step that pours a molten alloy into the cavity, the molten alloy comprising a second magnesium alloy having a second alloy composition, the second magnesium alloy having a liquidus temperature higher than that of the first magnesium alloy; and
a solidification step that cools and solidifies the molten alloy to obtain a complex magnesium alloy member in which a cast material comprising the second magnesium alloy is cast with the cast-in material.

5. The method for producing a complex magnesium alloy member as recited in claim 4,
wherein at least a part of the cast-in material is heated before the pouring step.

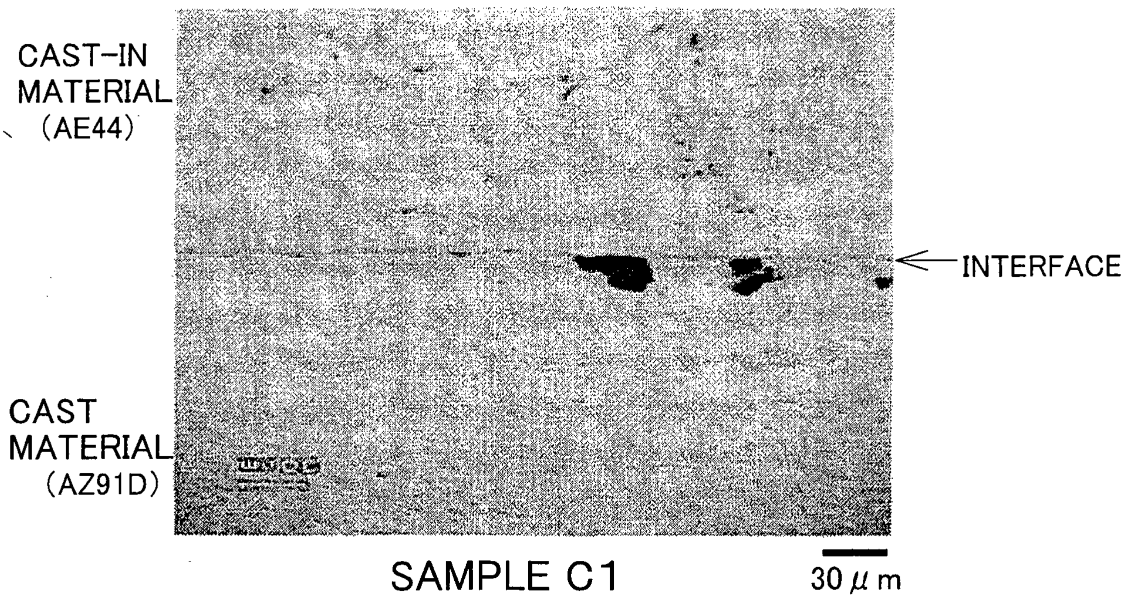
6. The method for producing a complex magnesium alloy member as recited in claim 4 or 5, wherein the method further comprises subjecting the complex magnesium alloy to at least one of heat treatment or plastic working after the solidification step.

FIG.1A



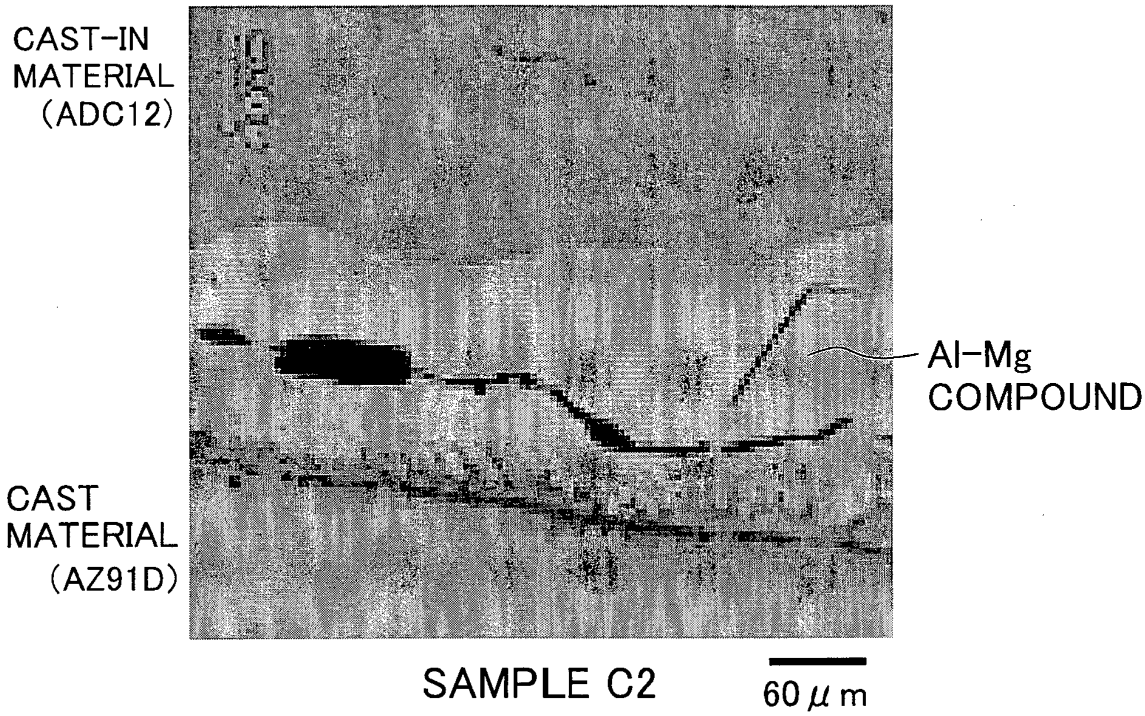
SAMPLE 1

FIG.1B



SAMPLE C1

FIG.1C



SAMPLE C2

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EUROPEAN SEARCH REPORT

Application Number
EP 13 18 3125

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

C22C
B22D
C22F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	16 December 2013	Chebeleu, Alice

CATEGORY OF CITED DOCUMENTS

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